5.—The petrology of the Wooramel Group (Lower Permian) in the Lyons River area, Carnarvon Basin, Western Australia.

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Abstract

In the Lyons River area, about 100 miles east of Carnarvon, Western Australia, the Wooramel Group (Lower Permian) comprises the Moogooloo Sandstone and the Billidee Formation. The Moogooloo Sandstone, overlying the Callytharra Formation with a conformable, disconformable or faulted contact, consists of orthoquartzite, often ferruginized, with minor orthoconglomerates. Gypseous carbonaceous shales are present towards the top of the formation.

The Billidee Formation, resting conformably on the Moogooloo Sandstone consists of fine to medium grained orthoquartzite and calcite-cemented sandstone, interbedded with gypseous carbonaceous shale. A laterally-persistent, fossiliferous unit is present at the top of the formation.

Introduction

The name "Wooramel Group" was first proposed by Condit (1935) and revised by Konecki *et al.* (1958) who described it as ". . . predominantly arenaceous sequence disconformably or unconformably overlying the Callytharra Formation, Lyons Group or Precambrian schist, or overlain conformably by, or changing laterally into the Byro Group." In the Lyons river area, only two formations of the Wooramel Group, the Moogoolo Sandstone and the Billidee Formation are exposed. No previous detailed work has been done on the Wooramel Group in the Lyons River area, although the area has been regionally mapped by the Bureau of Mineral Resources (Condon 1954, 1962, 1967).

An area about 110 miles east of Carnarvon, Western Australia (Fig. 1) was mapped in 1970. Rocks exposed are the Precambrian rocks of the Weedarra Inlier, and Permian rocks—the glacigene Lyons Group, the Callytharra Formation and the overlying Wooramel Group. Mapping was done by numerous ground traverses with the aid of aerial photographs. Twelve stratigraphic sections were measured. About 70 thin sections were examined with a petrological microscope. Some friable rocks were impregnated with plastic or Canada balsam before sectioning. Sediments are classified according to Pettijohn (1957).

Topography

The topography of the Lyons River area closely reflects the distribution of rock types. The Moogooloo Sandstone outcrops strongly as a strike ridge and dip slope, or as mesas and buttes. The sandstone lithologies of the Billidee Formation outcrop as low strike ridges, and the interbedded shales do not outcrop.

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Stratigraphy

The Lower Permian stratigraphy of the Lyons River is summarised in Fig. 2. The outcrop pattern and inferred subsurface extent of the Wooramel Group which, in the Lyons River area, comprises the Moogooloo Sandstone and the Billidee Formation, is shown on Fig. 3.

Structure and Tectonic History

The area mapped is in the south-easterly corner of the Merlinleigh Basin and in the west of the Bidgemia Basin, both sub-basins in the eastern Carnarvon Basin. The Weedarra Inlier (Precambrian) is the dominant structural element in the area mapped. Permian sediments are down faulted against the inlier by major faults. The Permian sediments strike north-south and dip to the west at about 5 degrees. Faulting is common in the Permian sediments. There are two dominant trends: strike faults, and faults trending at about 280 degrees. Most of these faults have a throw of less than 46 m.

Petrology of the Wooramel Group

In the Lyons River area, the Wooramel Group comprises the Moogooloo Sandstone and the overlying Billidee Formation. The group is dated as Artinskian (Early Permian).

Moogooloo Sandstone

The Moogooloo Sandstone consists of red, brown and white fine to coarse-grained orthoquartzites; subordinate arkoses (feldspathic sandstones) and orthoconglomerates. Minor interbedded silty shales are present in the upper part of the formation.

Orthoquartzite is the dominant lithology, grading compositionally into subarkose. Grain size ranges from 0.05 mm to 1.8 mm, with the majority of grains in the 0.2 to 0.5 mm range. Secondary overgrowth has resulted in many originally rounded grains becoming subangular. Sorting is moderate to good.

The dominant mineral in the sandstone suite is quartz, commonly with undulose extinction. Syntaxial growth on quartz grains is present in every sample examined. Pressure welding is observed in some juxta-positioned grains. Inclusions in quartz include tourmaline, zircon and muscovite. Microline is the only feldspar present, and ranges in abundance from almost nil

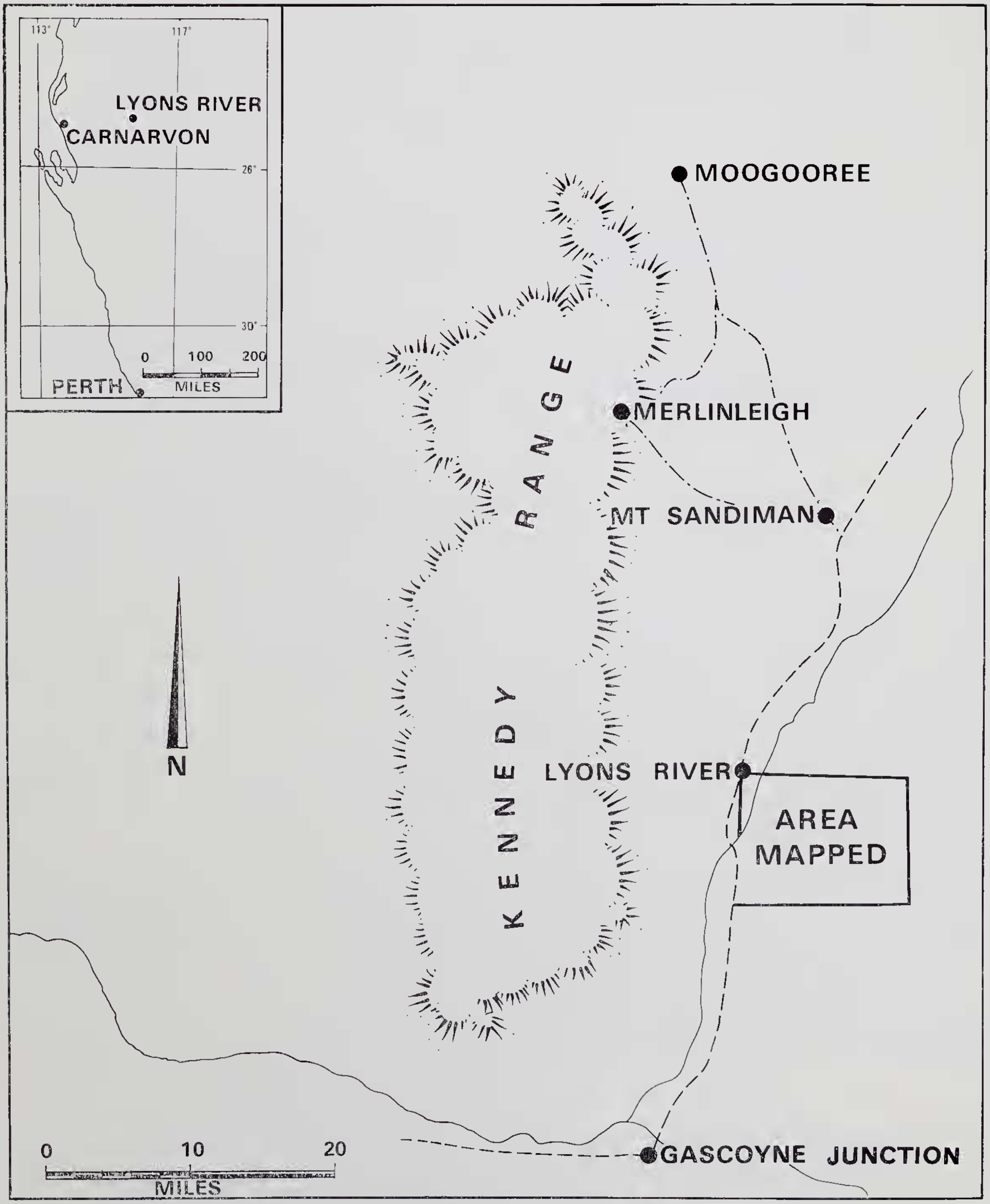

Figure 1—Locality map.

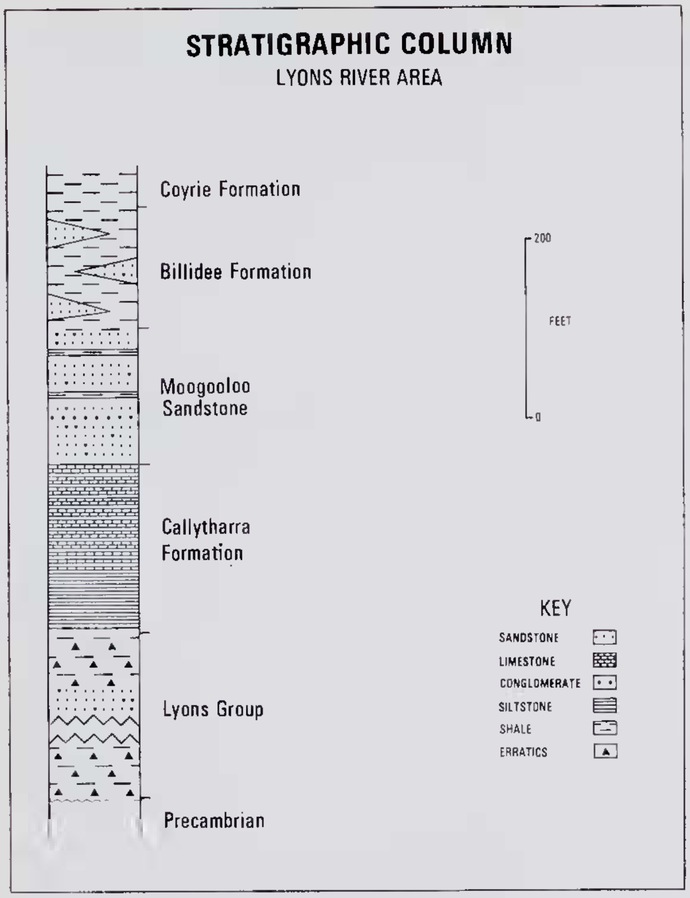

Figure 2—Stratigraphy of the Lyons River area.

to 9% of the detrital fraction. Lithic fragments are present in over 60% of the orthoquartzites, and in all of the subarkoses examined, fine-grained metaquartzite being by far the most abundant. Muscovite is a common detrital grain, in plates up to 1.3 mm long. Light-brown biotite is a common accessory.

No systematic study of the heavy mineral suite was undertaken, but a number of heavy mineral samples were examined. Euhedral to subhedral zircon and tourmaline are the most abundant minerals. Tourmaline is present in pleochroic yellow-green and dark grey-pink varieties. Both pink and colourless garnet are present. Rutile, sphene and staurolite are minor accessories. The detrital opaque minerals are ilmenite, with partial leucoxene coatings, and minor limonite.

The matrix is dominated by kaolinite, either coating grains or filling all interstitial spaces. In some samples, the clay has been completely ferruginized, resulting in a rock with a high proportion (up to 22%) of hematite with some limonite. Chlorite, sericite, microcrystalline quartz, gypsum, collophane and calcite are all minor, probably authigenic, constituents of the matrix.

Orthoconglomerates are volumetrically a very minor constituent of the Moogooloo Sandstone, occurring in beds up to 30 cm thick which persist laterally for up to 120 metres. The conglomerates are poorly sorted, the grain size ranging from 0.02 mm to 4 cm. The dominant detrital mineral is quartz, with minor secondary overgrowths. Other minor detrital grains are fresh microcline feldspar and lithic fragments. The matrix is made up entirely of hematite and minor limonite.

Dark-grey to brown, friable, carbonaceous silty shales occur near the top of the formation in beds up to 1.8 metres thick. The shales are interbedded with coarse-grained orthoquartzites and conglomerates containing the trace fossil *Palaeophycus* sp. The shales are poorly laminated and contain up to 15% carbonaceous matter. Silt-sized detrital grains, mainly quartz, are concentrated in lamellae up to 0.1 mm thick. Gypsum accounts for up to 12% of the mode, in laths up to 50 mm long, and is thought to be a primary mineral, although some recrystallization has occurred. Slight ferruginization has partially welded the clay-sized particles together.

Diagenesis is here discussed under three headings:

(a) Constructive diagenesis.

(b) Destructive diagenesis.

(c) Compactional effects.

The discussion is here confined to the more abundant sandstone suite.

(a) Constructive diagenesis. Under this category are grouped all diagenetic mineral growths and enlargements. The development of syntaxial

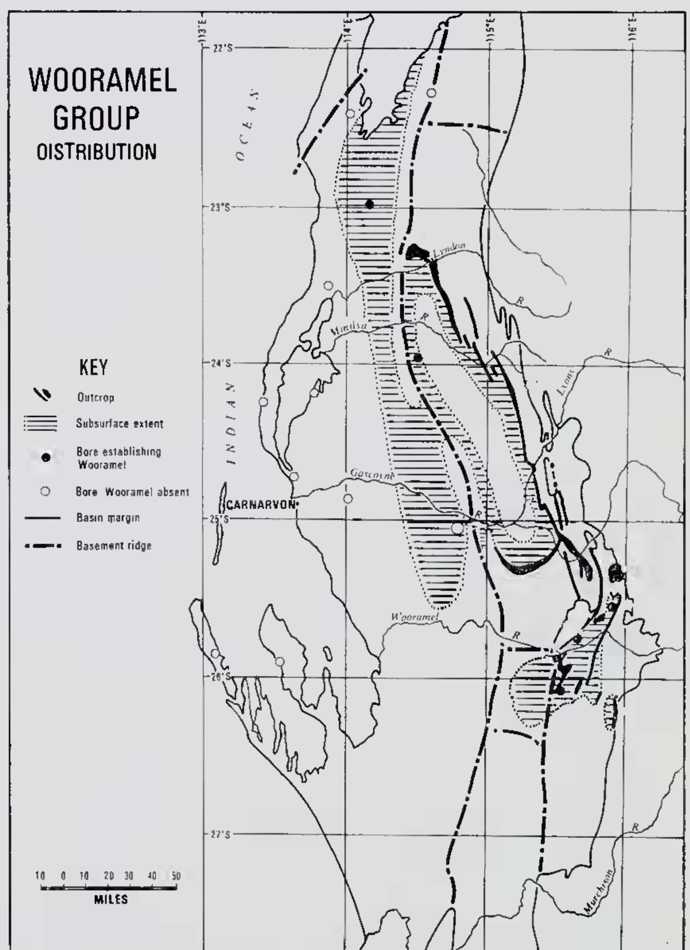

Figure 3—Distribution of the Wooramel Group (After Condon, 1967).

rims on quartz is the most common of these effects. Other diagenetic minerals are kaolinite, hematite and limonite, sericite, collophane, microcrystalline quartz, chlorite and calcite. Hematite and limonite were deposited after kaolinite, growing preferentially in the kaolinitic clay matrix.

(b) The principal destructive effect is the etching of quartz and feldspar by kaolinite. Hematite and limonite, where abundant, also etch quartz and feldspar. Tourmaline suffers noticeable solution, only fragments of once large detrital grains remaining.

(c) Compactional effects observed are bending of muscovite plates around detrital grains, and pressure welding of quartz grains at points of contact. The material which has been removed from areas of solution is thought to have been redeposited as syntaxial growths.

Billidee Formation

The Billidee Formation conformably overlies the Moogooloo Sandstone, and consists of orthoquartzites and calcite-cemented sandstones. Gypseous, carbonaceous silty shales, similar to the shales of the Moogooloo Sandstone, make up about 45% of the formation. Rare siltstones, often calcareous, and calcareous conglomeratic sandstones are also present. None of the units within the formation has any lateral persistence except the uppermost calcareous sandstone unit which contains abundant pelecypods. This is the only unit which can be traced along strike for more than 460 m. The uppermost unit is up to 6 m thick, persists throughout the whole of the area mapped, and is the only mappable unit in the formation. Fossils (apart from fossil wood) are found only in this unit.

All of the sandstones are thinly bedded, with bedding thicknesses ranging from 2.50 to 60 cm. They are predominantly fine to medium grained, the mean grain size being 0.2 mm. Nearly all of the sandstones are moderately well sorted, with moderate to poor rounding and low sphericity of detrital grains.

Quartz, often with undulose extinction, is the dominant mineral, averaging 60% of the mode. Fresh and slightly altered microcline comprises up to 40% of the mode, in grains up to 1.5 mm in diameter. Muscovite is common accessory, in plates, often bent by pressure, up to 0.4 mm long. Light-brown, slightly pleochroic biotite is present in some specimens. In one fine-grained orthoquartzite, recrystallized primary gypsum is interbedded with detrital quartz. Rare limonite pseudomorphs after pyrite are present in grains up to 1 cm in diameter. Oligoclase is present in one thin section.

Lithic fragments present in the sandstones include chert and occasional fragments of quartz-muscovite schist up to 14 cm in diameter, in the uppermost unit of the formation. Rare carbonate lithic fragments occurr, some containing unidentified Bryozoa, punctate brachiopods (perhaps *Permorthotetes sp.*) and also an unidentified calcareous alga. The lithic fragments are partially replaced by sparry calcite in isolated, often lenticular, patches. The carbonate lithic fragments contain between 3% and 20% sandsized detrital grains admixed with the carbonate, and are extensively ferruginized and cut by ferroan calcite veins. Rare ferroan calcite lithic fragments containing quartz and authigenic microcline are present in some calcite-cemented sandstones.

The non-opaque heavy mineral suite, in order of abundance, is tourmaline, zircon, colourless and pink garnet, rutile, sphene, staurolite and barite. The opaques are limonite and minor ilmenite.

There is great variety in the matrix of the sandstones of the Billidee Formation, with calcite, ferric oxides, clay minerals and chlorite all being major constituents in different rocks.

Calcite cement is present in a large number of the sandstone bodies within the formation. The cement consists of crystalline ferroan calcite, with patches of non-ferroan calcite and admixed clay minerals. The ferroan calcite cement consists of interlocking crystals, some up to 9 mm in diameter. In many of the calcite-cemented sandstones, the detrital grains are "floating" unsupported in the calcite matrix. Evidence of pressure solution is widespread, and suggests that the sediment was grain supported when deposited, with a relatively high proportion of detrital skeletal fragments. Pressure solution has been applied, either by sedimentary load or by tectonic stress, and has resulted in the solution of the carbonate skeletal fragments. Dissolved carbonate has been reprecipitated as ferroan calcite, producing the unsupported "floating" texture. The iron necessary for the production of ferroan calcite may have been derived from clay minerals, as outlined by Oldershaw and Scoffin (1967). Some skeletal fragments have escaped solution, especially in the uppermost unit of the formation.

Non-ferroan calcite is a minor constituent of the matrix, occurring as coatings, up to 0.03 mm thick, on detrital grains, and as isolated patches within ferroan calcite. There are two possible explanations for the origin of this non-ferroan calcite, the first being that the patches are remnants of original skeletal grains that have escaped pressure solution, and thus have not been converted to ferroan calcite. The second alternative is that calcite has been dissolved by pressure solution and reprecipitated, but because of an oxidizing micro-environment around detrital grains and in isolated patches, non-ferroan calcite has been deposited instead of ferroan calcite. Ferroan calcite can be deposited only in reducing conditions (Evamy, 1969). The second explanation is favoured by the author.

Ferric oxides are abundant in the matrix of some orthoquartzites, with hematite and limonite occupying up to 35% of the rock. The average is, however, about 4%.

Minor clay minerals are common in the matrix, occurring in isolated patches, often partially ferruginized, Colourless chlorite is a common matrix mineral, in scalar aggregates up to 1 mm in diameter, occupying up to 10% of the rock, the average being about 1%. The matrix also contains minor gypsum, in scalar aggregates.

Pressure effects are abundant in the Billidee Formation, with pressure welding of quartz and microcline grains, bending of micas and pressure solution of calcite. Quartz, and some microcline grains show secondary overgrowths, the material for the overgrowth probably being derived from pressure solution. In sandstones with abundant calcite cement, authigenic secondary growths are rare, and etching of quartz is common.

The fossils of the uppermost member of the Billidee Formation are recrystallized into blocky calcite, sparry in places. Dark lamellar organic matter (conchilium) is still present in many valves of *Oriocrassatella* sp., and is seen to pass through the sparry calcite, indicating that the spar is formed by replacement. *Oriocrassatella* sp., is also partially replaced by ferroan calcite in quite irregular patches. Replacement of calcite by ferroan calcite has, to the author's knowledge, not previously been recorded in the literature.

Borings, perhaps algal, are common in some pelecypods in the uppermost unit in the formation, penetrating up to 0.4 mm into the valve. The borings are infilled with ferroan calcite, of different composition (less iron) than the replacement ferroan calcite mentioned above.

Late-stage diagenetic effects observed in the Billidee Formation are ferruginization, sparry calcite veins and sparry infillings of fossils, together with the development of calcrete.

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